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Magnetohydrodynamics (MHD) Engineering Test Facility (ETF) 200 MWe Power Plant

Conceptual Design Engineering Report (CDER)

Volume III — Costs and Schedules

Gilbert / Commonwealth
Engineers / Consultants

September 1981

Prepared for
National Aeronautics and Space Administration
Lewis Research Center
Under Contract DEN 3-224

for
U.S. DEPARTMENT OF ENERGY
Fossil Energy
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MHD-ETF
CONCEPTUAL DESIGN
ENGINEERING REPORT

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3.0 COSTS

This section contains the estimated plant capital cost for the MHD-ETF. The estimated cost is subdivided into principal accounts, such as "Accessory Electrical Systems," based on the conventional Federal Energy Regulatory Commission (FERC) account structure. Definitions for each principal account are provided. The estimated cost in each principal account is further subdivided into identifiable structures and major equipment systems such as, "Medium Voltage Equipment." This is the lowest level of cost addressed in this report. However, discussions are provided describing: the cost data sources for compiling the estimates, cost parameters, allotments, assumptions, and contingencies. Uncertainties associated with developing the costs are quantified separately to show the costing confidence level achieved.

Appendix 3A provides details of the guidelines established in the preparation of the estimated costs. The appendix contains additional detail, in outline form, defining cost parameter and account contents.

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3.1 COSTING PROCEDURE

3.1.1 Principal Accounts

The estimate for the MHD-ETF has been organized into the DOE/MHD account structure, patterned after the FERC accounting structure used through-out the utility industry. Refer to Appendix 3A for "ETF Cost Estimate Format" information. The principal accounts and their content are as follows:

310 - Land and Land Rights
This account includes the cost of all land purchase and costs associated with the purchase of land for the project site.

311 - Structures and Improvements
This account includes the cost of all buildings and structures on the site, including yard facilities. Foundations for major equipment, even though included within the buildings are not listed with the structures but are costed with the major equipment items. Exceptions to this occur in the 317 account due to the difficulty in separating foundations from the building structure.

312 - Boiler Plant Equipment
This principal account contains the cost for the scope of yard coal handling, slag and ash handling, steam generator (HR/SR), the plant effluent control, the process water systems and other auxiliary systems related to the boiler plant equipment. In addition to equipment, costs here include equipment foundations, associated piping, instrumentation and related electrical equipment.

313 - Engines and Engine Driven Generators
Not applicable to this design.

314 - Turbogenerator Units
This account includes the bottoming cycle equipment associated with steam turbine generator power generation. In addition to the turbine generator itself, the account contains the main condenser and its auxiliaries, circulating water system (including the cooling tower), the steam piping systems, and the closed cycle cooling water system.

315 - Accessory Electrical Systems
This account contains the cost of equipment to supply station auxiliary power and the in-plant equipment associated with the power generation. Also included in this account is the station control equipment with the associated computer. The power conditioning equipment is included in the 317 account and the substation/switchyard equipment is costed in Account 350.

316 - Miscellaneous Power Plant Equipment
This account includes the cost of such things as the plant air supply system, station fire protection, industrial and sanitary

waste treatment, fuel oil supply, plant communications, and machine shop and stores equipment.

317 - <u>MHD Topping Cycle Equipment</u>
This account includes all topping cycle equipment, namely: the combustor and final coal preparation equipment; the channel, diffuser and magnet and their related systems; the electrical consolidation and inversion equipment; the oxidant supply and ASU systems; and the complete seed system.

318 - <u>Special Diagnostic Equipment</u>
The scope of this account is for equipment related to research and development purposes. No cost has been included since a requirement was not established.

319 - <u>Performance Evaluation Equipment</u>
As with Account 318, the scope has not been defined, and therefore cost has not been included.

350 - <u>Transmission Plant</u>
This account includes the cost of all the switchyard equipment downstream of and including the main power transformer.

In addition to the principal accounts itemized above, several other categories have been included by title only. These are:

1. Engineering - which covers the cost of plant design and engineering services including Construction Management.

2. Other Costs - which are the allowances for the equivalent of an "Owner's Cost" which in this case should be government field staff and project support personnel.

In addition to these items, two areas normally included are Escalation and Allowance for Funds used During Construction (AFDC). In this estimate they will not be included. The total cost will be "overnight" construction costs.

3.1.2 <u>Cost Parameters and Allotments</u>

Within each principal account, a breakdown of costs is provided to itemize the various cost items. Material costs are shown as two separate values: one is major components for the designed and engineered major commodities; the other is "Balance of Account" for materials associated with the major components but not furnished as a part of these components, such as related foundations, instrumentation, local electric equipment and piping. These material costs are developed from a combination of sources, including vendor quotes, current in-house estimate prices, the Supplemental Data supplied in Section 5.2.3, or comparable system costs from other in-house projects. The installation of the components and other material costs represents all the field labor, but at a level representing only the base labor and fringe rate, exclusive of individual contractor's costs, profit and overhead. The wage rates represent

an average based on labor rates in 30 major U.S. cities. The quantity information used in developing the component material and labor costs (which together are the direct cost), was developed from a takeoff of the MHD conceptual drawings, supplemented by quantitative information from similar projects in those areas not yet designed in detail for the MHD project.

The indirect costs are based on a percentage factor of the direct labor costs. This factor has been established at 70 percent of the direct labor and includes such things as temporary facilities, labor wage expenses, contractor supervision, overhead, administrative and profit.

A contingency representing an allowance for undefined aspects of the account including overtime, underestimated hours, late deliveries, etc., has been established at 15 percent of the total direct and indirect costs for well-defined elements. Lesser-defined elements are calculated with a 20 percent factor, and portions of the high technology elements are based on a 30 percent factor. In the case of engineering services, the estimate is detailed on the basis of total cost less contingency at 8 percent with 2 percent for preliminary engineering, 4 percent for engineering plans and specifications, and 2 percent for construction engineering management. Contingency for engineering services is 20 percent (See Appendix 3A).

For other cost, a percentage of 2-1/2 percent is calculated from the sum of the direct, indirect and professional services cost. Again, a 20 percent contingency factor is applied (See Appendix 3A).

The sum of all of these columns yields a total cost for each principal account, exclusive of the principal account categories from above that do not have assigned account numbers (engineering, etc.).

The plant location* is assumed to have railway and utility access. The topography of the land is assumed to need only nominal earthwork. All material dollar costs are first quarter 1981 and expressed in thousands of dollars. All materials costs are F.O.B. plant. The cost for initial fuel supply and other consumables has been excluded. All installation dollar costs are based on wage rates currently in effect. The data is from the current Means Construction Labor Rate publication. Quantitative information is from construction drawings. A unit of measure and quantity is shown for each account. Unit manhour costs are from Gilbert Associates, Inc. (GAI) historical data and the current Means Building Construction Cost Data publication.

* Since a specific site location has not been identified, location has been considered to represent "Middletown", U.S.A. Cost adjustments for a Montana site are addressed in Section 3.3.

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3.2 COSTING BASES

3.2.1 Conversion Tables for Constant Dollars

The conversion factors in Table 3-1 are used to adjust costs from their stated time frame. The factors were developed on the basis of data presented in the Handy Whitman Index; specifically, the Electric Utility Construction Index for the Plateau Region. The data covers each year of the last decade to first quarter 1981.

This information can be used in two ways: first, to take costs that originated prior to the present and escalate to a present day by multiplying the factor by the known cost (as done in this estimate effort); secondly, the data can be used to de-escalate values for comparison with other data on an earlier-year basis by dividing the present year cost by the applicable factor. The table shows separate values for each primary account. This was done since the estimate was developed on the basis of the FERC code, and Handy Whitman is available with FERC code principal accounts. The only exception in developing the table was that Handy Whitman does not have equivalent data for the 317 topping cycle equipment. In this case, the data for 314 account was used for the 317 equipment also, since it is similarly affected.

TABLE 3-1

ESCALATION FACTORS*
FOR
F.E.R.C. SUMMARY ACCOUNTS (TOTAL COST)
PLATEAU REGION

YEAR	311	312	314	315	316	317	350
1970-81	2.79	2.81	2.72	2.57	2.52	2.72	2.65
1971-81	2.55	2.63	2.51	2.46	2.36	2.51	2.49
1972-81	2.35	2.42	2.24	2.25	2.20	2.24	2.31
1973-81	2.23	2.32	2.16	2.13	2.09	2.16	2.25
1974-81	2.01	2.16	2.05	1.97	1.93	2.05	2.02
1975-81	1.53	1.66	1.79	1.57	1.59	1.79	1.55
1976-81	1.52	1.52	1.52	1.46	1.51	1.52	1.43
1977-81	1.46	1.42	1.38	1.36	1.38	1.38	1.34
1978-81	1.38	1.32	1.31	1.22	1.26	1.31	1.27
1979-81	1.23	1.2	1.17	1.18	1.17	1.17	1.21
1980-81	.87	1.14	1.08	1.08	1.06	1.08	1.09

*Factor x base year amount = total value including escalation

3.2.2 Vendor Data

Vendor data refers to costs for equipment quoted by a vendor for specific component application. This has a very high degree of reliability. In this effort vendor data has been utilized in several different ways. The first of

these would be in utilizing the price furnished by the vendor directly in the cost estimate. Examples of this approach as applied to this estimate effort are: the auxiliary boilers, the main condenser, the station air compressors, the chimney, the combustion turbines for emergency power, and the major cranes.

Vendor data was also established for individual components, by direct extraction from in-house current price books. Examples are the steam turbine generator and the majority of electrical equipment associated with the station auxiliaries. These prices are current and reliability is generally equivalent to direct vendor furnished prices.

A third source of "vendor data" is from estimates for MHD total system cost. These were derived from an equivalent system for which costs were established, or from estimates provided by the system designer. (See Section 3.2.4)

3.2.3 Reference Cost Data

Reference cost data has been used as a verification of values established independently for the high technology components. The reference source data could have also been used as the primary costing basis on high technology component parts, since source cost information was not available at the time this estimate was prepared. One such source is the Cost Estimation Procedure for Oxygen Enriched Early Commercial MHD Power Plants and Conventional Fossil Steam Plants with Flue Gas Desulfurization, dated September 17, 1980 and prepared by GAI, for DOE Division of Magnetohydrodynamics. As planned, the data was used in comparisons with independently developed costs of prime accounts to evaluate confidence levels for those areas.

Cost estimates have been provided for their respective systems by NASA, ANL, Lotepro, and NML (See Section 5.2.3). Individual items may differ from those prepared by GAI but final totals are in general agreement. Cost estimates calculated for the inverter components by GAI are consistent with estimates received from Westinghouse for that equipment.

3.2.4 Comparison with Analogous (Constructed) Plant Subsystems

Comparisons with analogous plant subsystems have several different applications in this MHD estimating effort. The first of these is use of the reference sources listed in Section 3.2.3. A second is the use of the GAI commercial MHD (930 MWe) design where the commercial plant subsystems were scaled to the equivalent ETF level; not as a direct costing source but as a check to confirm the relative costing level of various subsystems. A third application is the use of conventional plant cost information available from in-house data, such as a current (1981) estimate for a fossil plant coal conversion, a total fossil plant estimate recently costed at a definitive level of detail, and the quantity information extracted from a recently constructed fossil power plant. In these cases the analogous system cost was scaled at the equivalent MHD-ETF size and then compared with the developed costs. Examples of where this approach was used are the yard coal handling system, ash handling system, the various fans and compressors, and the coal injection system.

3.2.5 Judgment Factors

The use of judgment factors in developing the estimate was held to a minimum and confined generally to minor, totally undefined areas whose costing impact would not significantly affect total estimate costs. An example of the use of judgment is in defining the scope of buildings not fully detailed (except for input from engineering descriptions as to the type of structure). Another significant example involves the electrical bulk quantity. In this case the MHD was costed equivalent to a 400 MWe fossil plant. Some judgment was also used in establishing piping systems where the prevalent pipe size was established for use as a scaling basis from comparable analogous piping systems.

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3.3 PRINCIPAL ACCOUNT VALUES

The total capital cost estimate for the MHD-ETF in first quarter 1981 dollars is $362,500,000. This cost does not include escalation or AFDC. Based on a net plant output of 202 MWe, this cost equates to $1795 dollars per kW. If future escalation and interest are assumed to average 9 percent each year over the next 10 years, then escalation and AFDC through construction of the ETF plant would amount to 236 percent. This would yield a direct capital cost in 1991 of $774,000,000. One other consideration is the cost impact of specifying a Montana site. If the scope were to remain unchanged, the pure cost differential for regional cost factor and productivity construction labor would yield about an eight percent reduction in direct costs. Table 3-2 presents the cost for the MHD-ETF in a format consistent with the procedures addressed in Section 3.0.

3.3.1 Material Cost and Balance of Account

The major material cost level for the subject estimate is over $149,000,000. Of this total amount, more than 60 percent was estimated independently by "others" as identified in Section 3.2.3, last paragraph. The balance of this category was estimated in accordance with procedures outlined in Section 3.1.2.

The Balance of Account (BOA) direct cost level is almost $41,000,000. The majority of this cost represents GAI developed costs for civil/structural piping, insulation and some electrical scope associated with the major material. These BOA costs provided "by others" have been incorporated.

Several adjustments were required in the item of costs by "others". In the case of the Heat Recovery/Seed Recovery (HR/SR) equipment, a contingency of 50 percent was included. Estimation guidelines did not permit a value at this level. The cost difference, 50 percent vs 30 percent is compensated for in the BOA category. Other adjustments concern labor and contingency (refer to Sections 3.3.3 and 3.3.4 for details).

3.3.2 Construction Costs

Construction costs include the field labor costs and their associated indirect costs. The estimated total for this category is $80,000,000, of which $47,100,000 represents the direct cost portion. The basis for the indirect portion is discussed in Section 3.1.2.

This approach to direct and indirect costs has necessitated some adjustments to costs as found in Section 5.2.3, "Supplemental Data". The labor values for the HR/SR supplied by others appear to be subcontract equivalent values. In GAI estimates these values appear as part of the direct cost. The indirect cost factor was used to "return" these costs to direct cost, and adjust the indirect costs accordingly.

In the case of the magnet costs (317.3), indirects were included by NML at a much lower rate than used in GAI estimates. In the NML case, the installation cost basis includes indirect costs associated with direct labor, while the

TABLE 3-2

MHD-ETF COST ESTIMATE*

(All costs in 1,000's)

Account Number	Description	Unit	Quantity	Material Cost Mjr Comp	Material Cost BOA	Inst. Cost	Indir. Cost	Contin.	Total Cost
310	Land & Land Rights	Acre	190	-	950	-	-	142	1,092
311	Structures & Improvements								
311.1	Improvements to Site	Acre	169	-	2,409	1,824	1,277	827	6,337
311.2	MHD Building	Sq. Ft.	34,000	-	1,998	1,112	779	583	4,472
311.3	Turbine & Compressor Buildings								
311.31	Steam Turbine Building	Sq. Ft.	18,820	-	2,449	877	614	591	4,531
311.32	Control Complex	Sq. Ft.	1,370	-	79	48	34	32	193
311.33	Compressor Building	Sq. Ft.	15,680	-	1,707	497	348	383	2,935
311.4	Heat Recovery/Seed Recovery Building	Sq. Ft.	14,000	-	3,073	843	590	676	5,182
311.5	Coal Crusher House	Sq. Ft.	3,030	-	388	122	85	89	684
311.6	Coal Preparation Building	Sq. Ft.	3,220	-	408	120	84	92	704
311.7	Coal Feed Building	Sq. Ft.	1,570	-	192	60	42	44	338
311.8	Seed Feed Building	Sq. Ft.	1,570	-	192	60	42	44	338
311.9	Service Buildings								
311.91	Service Bldg/Machine Shop	Sq. Ft.	7,840	-	473	282	197	143	1,095
311.92	Warehouse	Sq. Ft.	8,000	-	187	77	54	48	366
311.10	Other Process Buildings and Structures								
311.10.1	Inverter Building	Sq. Ft.	18,820	-	909	340	238	223	1,710
311.10.2	Water Treatment Building	Sq. Ft.	4,700	-	324	117	82	79	602
311.10.3	Auxiliary Boiler Building	Sq. Ft.	3,000	-	253	98	69	63	483
311.10.4	Industrial Waste Treatment	Sq. Ft.	11,000	-	289	92	64	67	512
311.10.5	Other Misc. Structures	Sq. Ft.	12,900	-	457	292	204	191	1,144
	Total 311			-	15,787	6,861	4,803	4,175	31,626

*All costs are first quarter 1981 dollars

TABLE 3-2 (Continued)

MHD-ETF COST ESTIMATE

(All costs in 1,000's)

Account Number	Description	Unit	Quantity	Material Cost Mjr Comp	Material Cost BOA	Inst. Cost	Indir. Cost	Contin.	Total Cost
312	Boiler Plant Equipment								
312.1	Coal Handling & Processing	ton/h	83	6,161	1,466	2,510	1,757	1,784	13,678
312.2	Slag & Ash Handling	ton/h	14	760	448	374	262	277	2,121
312.4	Steam Generator								
312.41	HR/SR Boiler	ea.	1	13,984	3,570	5,716	4,000	8,180	35,450
312.42	Other Steam Gen. Equip.	lot	1	200	309	164	115	158	946
312.5	Effluent Control								
312.51	Electrostatic Precipitator	ea.	1	6,680	70	167	117	1,055	8,089
312.52	Other Effluent Control Equipment	lot	1	2,004	267	1,343	940	683	5,237
312.6	Auxiliary Boiler Systems								
312.61	Afterburner Air Equipment	lot	1	100	10	37	26	26	199
312.62	Gas Recirc. Fans	ea.	3	60	2	8	6	11	87
312.63	Aux. Boiler System	ea.	2	1,092	803	373	261	379	2,908
312.64	Service Water Cooling Sys.	lot	1	91	570	571	400	245	1,877
312.7	Other Boiler Plant Systems								
312.71	Cycle Makeup	lot	1	329	156	168	118	154	925
312.72	Condensate System	lot	1	718	535	339	237	274	2,103
312.73	Feedwater System	lot	1	2,331	1,207	462	323	649	4,972
312.74	Other Misc. Systems	lot	1	116	524	538	377	233	1,788
	Total 312			34,626	9,937	12,770	8,939	14,108	80,380

TABLE 3-2 (Continued)

MHD-ETF COST ESTIMATE

(All costs in 1,000's)

Account Number	Description	Unit	Quantity	Material Cost Mjr Comp	Material Cost BOA	Inst. Cost	Indir. Cost	Contin.	Total Cost
314	Turbogenerator Units								
314.1	Steam Turbine Generator and Auxiliaries	MWe	128	10,600	489	1,005	704	1,920	14,718
314.2	Condenser and Auxiliaries	ea.	1	1,427	31	230	161	277	2,126
314.3	Circulating Water System								
314.31	Cooling Towers	ea.	2	2,366	137	462	323	493	3,781
314.32	Other System Equipment	lot	1	635	1,363	567	397	444	3,406
314.4	Steam Piping Systems	lot	1	-	2,451	1,141	799	878	5,269
314.5	Other Turbine Plant Equip.	lot	1	469	318	231	162	177	1,357
	Total 314			15,497	4,789	3,636	2,546	4,189	30,657
315	Accessory Electric Systems & Equipment								
315.1	Medium Voltage Equipment	lot	1	2,378	1,451	116	81	604	4,630
315.2	Low Voltage Equipment	lot	1	1,945	-	34	24	300	2,303
315.3	Plant Control Equipment	lot	1	5,682	190	1,923	1,346	1,828	10,969
315.4	Bulk Commodities	lot	1	-	3,456	3,979	2,785	2,044	12,264
315.5	Other Accessory Electric Equipment	lot	1	1,082	96	210	147	230	1,765
	Total 315			11,087	5,193	6,262	4,383	5,006	31,931

TABLE 3-2 (Continued)

MHD-ETF COST ESTIMATE

(All costs in 1,000's)

Account Number	Description	Unit	Quantity	Material Cost Mjr Comp	Material Cost BOA	Inst. Cost	Indir. Cost	Contin.	Total Cost
316	Misc. Power Plant Equipment								
316.1	Plant Air System	cfm	1,000	214	241	214	150	123	942
316.2	Waste Treatment Equipment	lot	1	760	406	338	237	261	2,002
316.3	Fuel Oil System	lot	1	258	141	159	111	101	770
316.4	Other Misc. & Gen. Equip.	lot	1	1,256	148	402	281	313	2,400
	Total 316			2,488	936	1,113	779	798	6,114
317	MHD Topping Cycle Equipment								
317.1	Combustion Equipment	lot	1	12,887	343*	2,811	1,968	5,403	23,412
317.2	MHD Generator System	ea.	1	8,064	-	277	194	2,560	11,095
317.3	Magnet System	ea.	1	33,446	80*	4,470	3,129	12,338	53,463
317.4	Electrical Consolidation** & Inversion	lot	1	8,047	197	170	119	2,560	11,093
317.5	Oxidant Supply System	lot	1	6,250	218	2,024	1,417	1,486	11,395
317.6	Seed System	lot	1	4,231	361	1,866	1,306	1,553	9,317
317.7	Air Separation Unit	lot	1	11,610	837*	3,480	2,436	2,755	21,118
	Total 317			84,535	2,036	15,098	10,569	28,655	140,893
318	Special Diagnostic Equipment	lot	0	-	-	-	-	-	-
319	Performance Evaluation Equipment	lot	0	-	-	-	-	-	-
350	Transmission Plant	lot	1	980	1,200	1,336	935	668	5,119
	Subtotal Direct Costs			149,213	40,828	47,076	32,954	57,741	327,812
	Engineering						21,610	4,318	25,928
	Other Costs						7,300	1,460	8,760
	Total Cost								$362,500

* Equipment foundation costs included with buildings in 311.
** Portions of consolidation included with 317.2.

indirect category contains the remaining portion of these costs. As with the HR/SR costs, adjustments were made to the installation cost and indirect cost categories to be consistent with project standards.

With the Lotepro furnished costs (317.5 and 317.7), indirect costs were provided but were also adjusted to be consistent with GAI costing procedures.

3.3.3 Contingency Assessment

Contingency for the project has been evaluated at $57,741,000, excluding contingency on engineering and other costs. Section 3.4.3 discusses the various contingency factors and their values. The 30 percent factor was limited to: 312.41, HR/SR (refer to Section 3.3.1); 317.1, Combustion Equipment; 317.2, MHD Generator; 317.3, Magnet System; and 317.4, Electrical Consolidation and Inversion. The 20 percent factor was limited to: 311.10.5, Other Miscellaneous Structures; 312.42, Other Steam Generator Equipment; 312.71, Cycle Makeup Water; 314.4, Steam Piping Systems; 315.3, Plant Control Equipment; 315.4, Bulk Commodities; and 317.6, Seed System. All other accounts utilized the nominal 15 percent factor. The exception to this is the 20 percent factor used for Engineering and Other Costs (See Section 3.1.2).

3.3.4 Engineering and Other Costs

Both of these categories were calculated and presented exactly as described in Section 3.1.2. The Engineering Cost, including contingency is $25,928,000. Other Costs, including contingency, are $8,760,000.

3.4 CONFIDENCE LEVELS

3.4.1 Major Uncertainties

The most uncertainty is expected in the cost data from the specific sources discussed in Section 3.2.3, for the topping cycle high technology systems and components. This uncertainty exists even with the latest cost information from vendors, since statistical construction data does not exist.

A second area of uncertainty is that of the plant control system, since a firm detailed definition of that system has not been developed. In addition, the piping bulk quantity basis and electrical bulk quantity basis, as noted in Section 3.2.5, must be considered uncertainties because the plant engineering has not progressed to the point of actual detailed design.

3.4.2 Subsystem Cost Tolerances

The bottoming cycle subsystem costs have tolerances in the range of 10 to 15 percent, which is consistent with those experienced in an equivalent conventional power plant. This tolerance refers to the subsystems depicted on the drawings, and does not reflect probabilities of subsequent design changes.

3.4.3 Plant Cost Tolerances

Major cost uncertainties discussed in Section 3.4.1, represent approximately 50 percent of the direct costs. The conventional subsystems which represent half of the toal direct cost have tolerances with a high confidence level. Costs will also be impacted by a specific site location, with actual utility accesses, water availability, foundation requirements and other site conditions effecting design.

To assess actual range of total plant cost uncertainties, estimates of principal account tolerances correlated to the assigned contingencies were made. These tolerances were all taken as plus, in the direction to increase costs, and are indicated in Table 3-3 below:

TABLE 3-3

CONTINGENCY AND TOLERANCE PERCENTAGES

Acct. No.		Contingency %	Tolerance %
310	Land & Land Rights	15	10
311	Structures & Improvements (except 311.10.5)	15	10
311.10.5	Other Misc. Structures	20	30
312	Boiler Plant Equipment (except 312.42, 312.71, 312.41)	15	10
312.41	HR/SR Boiler	30	50
312.42	Other Steam Gen. Equip.	20	30
312.71	Cycle Makeup	20	30

TABLE 3-3 (Cont'd)

Acct. No.		Contingency %	Tolerance %
314	Turbogenerator Units (except 314.4)	15	10
314.4	Steam Piping Systems	20	30
315	Acces. Elect. Systems & Equip. (except 315.3, 315.4)	15	10
315.3	Plant Control Equip.	20	30
315.4	Bulk Commodities	20	30
316	Misc. Power Plant Equip.	15	10
317.1	Combustion Equipment	30	50
317.2	MHD Generator System	30	50
317.3	Magnet System	30	50
317.4	Elect. Consol. & Inversion	30	50
317.5	Oxidant Supply System	15	10
317.6	Seed System	20	30
317.7	Air Separation Unit	15	10
350	Transmission Plant	15	10

Those items in the 10 percent uncertainty range totaled $152,500,000; those in the 30 percent range totaled $40,800,000; those in the 50 percent range totaled $134,500,000. If all tolerances were at their extremes, plant capital costs would be $422,800,000 instead of $327,800,000, or an overcost of 29 percent.

APPENDIX 3A

DOE/MHD GUIDELINES	ISSUE DATE
PART A - ETF COST ESTIMATE FORMAT	6/24/81
PART B - ETF CODE OF ACCOUNTS	6/24/81

APPENDIX 3A - PART A

DOE/MHD
ETF COST ESTIMATE FORMAT

ACCT NO.	CODE OF ACCOUNTS DESCRIPTION	COST BASIS		MATERIAL COST		INST COST	INDIR COST	CONTIN	TOTAL COST
		UNIT	QUANTITY	MJR COMP	BOA				
	Direct Account (See attachment Part B)	xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
	SUBTOTALS			xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
	ENGINEERING SERVICES			-	-	xxxx	-	xxxx	xxxx
	OTHER COSTS			xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
	TOTAL ESTIMATED COSTS					xxxx	xxxx	xxxx	xxxx

DOE/MHD
ETF COST ESTIMATE FORMAT NOTES

A. Utilize DOE/MHD-ETF Cost Estimate Format to present the cost estimate. This will function as a "Summary of the Cost Estimate".

B. Utilize the ETF Code of Accounts described in Part B.

C. This cost data shall have detail cost back-up sheets included for this Cost Estimate. All estimates shall clearly identify the basis, methods, and assumptions employed in preparation of the estimate. Essential elements of this information shall be identified in the "Summary of the Cost Estimate" and shall be explained in appropriate detail in the detail cost back-up sheets.

D. Use the following definitions:

1. Cost basis shall be current fiscal year (FY) dollars.

2. Costs should be shown in thousands of dollars.

3. UNIT - Unit of measure for each account.

4. QUANTITY - Quantity for each account based on the unit of measure.

5. MATERIAL COST - Total material cost for each account (subdivided as follows).

   MJR COMP - Total major component material cost delivered to the site. (Major components are those major purchased items which are engineered, designed, fabricated, shipped, and in some cases, erected by one supplier or manufacturer).

   BOA - Total cost for Balance of Account materials delivered to the site.

6. INST. COST - Total direct installation cost for each account.

7. INDIR. COST - Total indirect construction cost for each account. (Identify breakdown of the procedure used in applying that cost to the estimate).

8. CONTIN. - Total contingency cost for each account. For this conceptual design the contingency for structures, improvements, and systems shall be as follows:

   Well-defined elements - use 15 percent of combined total of direct and Indirect.

   Lesser defined elements - use 20 percent of combined total of Direct and Indirect Cost.

High technology elements (with high degree of uncertainty) - use 30 percent of combined total of Direct and Indirect cost.

(Identify the procedures used in applying those costs to the estimate).

9. TOTAL COST - Total of all material, installation, indirect, and contingency costs for each account.

10. ENGINEERING SERVICES - Total cost of all professional services. Apply the following percentages to Total Plant Cost, less the contingency:

    Preliminary Engineering = 2 percent
    Engineering Plans and Specifications = 4 percent
    Construction Engineering Management = 2 percent
    Engineering Contingency = 20 percent of Total Engineering Cost

11. OTHER COSTS - Allow 2.5 percent of the sum of the Direct, Indirect, and Engineering services for government field staff, legal fees, etc. Add 20 percent of this calculated sum for contingency in this account.

E. ESCALATION - Do not include in this estimate. (Provide as a separate part of the estimate an allowance for escalation through the construction period, projected to be started in FY 87, and start of operation in FY 91).

F. ALLOWANCE FOR FUNDS DURING CONSTRUCTION (AFDC) - Do not include AFDC in this estimate.

APPENDIX 3A - PART B

DOE/MHD
ETF CODE OF ACCOUNTS

ACCT. NO.		DESCRIPTION	SPECIFIC NOTES
310		Land and Land Rights	
311		Structures and Improvements	(1)
	311.1	Improvements to Site	
	311.2	MHD Building	
	311.3	Turbine and Compressor Buildings	
	311.4	Heat Recovery/Seed Recovery Building (HR/SR)	
	311.5	Coal Crusher House	
	311.6	Coal Preparation Building	
	311.7	Coal Feed Building	
	311.8	Seed Feed Building	
	311.9	Service Buildings	(2)
	311.10	Other Process Buildings and Structures	(3)
312		Boiler Plant Equipment	
	312.1	Coal Handling and Processing	(4),(4a)
	312.2	Slag and Ash Handling	(5)
	312.3	(not used)	(6)
	312.4	Steam Generator (HR/SR boiler)	(7)
	312.5	Effluent Control	(8)
	312.6	Auxiliary Boiler Systems	(9)
	312.7	Other Boiler Plant Systems	(10)
313		Engines and Engine-Driven-Generators	(11)
314		Turbogenerator Units	
	314.1	Steam Turbine Generator and Auxiliaries	
	314.2	Condenser and Auxiliaries	
	314.3	Circulating Water System	(12)
	314.4	Steam Piping Systems	(13)
	314.5	Other Turbine Plant Equipment	(14)
315		Accessory Electric Systems and Equipment	
316		Miscellaneous Power Plant Equipment	(15)
317		MHD Topping Cycle Equipment	
	317.1	Combustion Equipment	(16)
	317.2	MHD Generator System	(17)
	317.3	Magnet System	(18)
	317.4	Electrical Consolidation & Inversion	(19)
	317.5	Oxidant Supply System	(20)
	317.6	Seed System	(21)
	317.7	Air Separation Unit (ASU)	(22)
	317.8	Miscellaneous MHD Topping Cycle Support Equipment	

ACCT. NO.	DESCRIPTION	SPECIFIC NOTES
318	Special Diagnostic Equipment	(23)
319	Performance Evaluation Equipment	(24)
350	Transmission Plant	(25)

DOE/MHD
ETF CODE OF ACCOUNTS
GENERAL NOTES

A. The modified FERC "ETF Code of Accounts" and these notes shall be a guide in developing and utilizing the final code of accounts for the ETF cost estimate.

B. These notes shall be a guide in subdividing accounts and additional subaccounts. This permits more accurate definition of the cost of the plant. Individual subaccounts shall be included for each major component, structure, or subsystem.

C. If the total cost of an account or subaccount is greater than 5 percent of the total estimated plant cost, the account or subaccount should be subdivided into its next lower level of detail.

D. Individual component or subsystem services such as foundations, structural steel supports, and access platforms shall not be included in account 311. These costs shall be included as part of the BOA material cost and installation cost for the component or subsystem.

E. All piping; ducting; and electrical, mechanical, and instrumentation and control equipment within a subsystem should be included in the cost of the subsystem.

SPECIFIC NOTES

1. Subdivide the building accounts into subaccounts for each individual building or major building area. (Example: If subaccount 311.3 Turbine and Compressor Buildings includes a separate building for the oxidant compressors, and a facility control room, provide separate subaccounts under 311.3 for each of these buildings). All building services including cranes should be included in the cost of the building.

2. Include all office, shop, warehouse, and maintenance buildings.

3. Include all other process buildings and structures such as the water treatment, industrial waste treatment, and Air Separation Unit buildings.

4. Include all equipment from the initial coal unloading point up to and including coal storage prior to final preparation.

4a. Final preparation includes drying and pulverizing.

5. Include all equipment from the initial collection equipment up to the storage area.

6. Do not use account 312.3.

7. Include furnace, superheater, reheater, high temperature economizer, and oxidant heater. Itemize each separately. (Also include separate low temperature economizer.)

8. Include Electrostatic Precipitator (ESP) and all other equipment from the steam generator (HR/SR boiler) outlet up to and including the chimney. (Does not include separate low temperature economizer.)

9. Include Afterburner air system, supplementary firing system and other ancillary systems for operation of the steam generator. Itemize each system separately.

10. Include the condensate system, boiler feedwater system, and boiler plant related water treatment system.

11. Do not use account 313.

12. Include a subaccount for the cooling towers.

13. Include main steam, hot and cold reheat steam, extraction steam, and bypass steam systems.

14. Include all accessory electric systems such as: the system from the MHD power conditioning equipment and steam turbine generator up to the transmission plant; emergency or standby power systems; wire and cable systems; Integrated Control System; and Data Acquisition System.

15. Include all equipment and subsystems not otherwise identified. (Examples: fire protection system, station maintenance equipment, fuel oil system).

16. Include the combustor, all coal injection equipment, initial slag collection equipment at the combustor, and all final coal preparation equipment not included in account 312.1.

17. Include the nozzle, generator channel, and diffuser.

18. Include the magnet and each support system.

19. Include all power conditioning and electrode control equipment.

20. Include all equipment from the outside air inlet through the delivery piping to the combustor, including the main oxidant compressors, compressor drives, mixing chamber, and piping. (This does not include the ASU.)

21. Include all seed unloading, storage, preparation, injection, transport, separation, and reprocessing subsystems and equipment.

22. Include ASU from ambient air inlet to oxygen supply pipe to the mixing chamber.

23. Include all equipment, instrumentation, or subsystems provided specifically for research purposes.

24. Include all equipment, instrumentation, or subsystems specifically provided to permit testing of high technology systems for proof of design

before integrated plant operation. (Examples: bypass scrubber and stack to permit MHD topping cycle operation without the steam generator (HR/SR); addition of oil firing to HR/SR for independent tests; alternate electric load).

25. Include all transmission plant equipment located at the facility including the main transformers and switchyard.

4.0 SCHEDULES

Utilities, municipalities, and industries need to accurately plan capital expenditures and additional load capabilities. Both the public and investors have become more aware of business problems; thus, a greater focus has been placed on setting and obtaining goals within given time frames and budget restraints. These restraints plus the size and complexity of projects have placed major responsibilities on accurate planning and scheduling for project control.

The project schedule is the vehicle used to formalize the project plan and to relate time, tasks and resource expenditures to a specific commitment made by the corporation for the performance of work. The planning function supports management in:

1. Defining the scope of work.

2. Developing early decisions on goal setting.

3. Assigning responsibilities.

4. Establishing report targets.

5. Defining problem areas and resolutions.

6. Fostering improved communications and work flow on the project.

Schedules are reviewed by engineering, purchasing, construction, and startup personnel before being submitted to management for final review and approval. Once approved, the schedules become part of the signed contract.

Final contract provisions provide the basis for determining the extent of planning and scheduling support required on any given project. The planning engineer will formalize the methods, procedures, and format to be used with project management prior to undertaking the development and implementation of a detailed integrated project schedule.

The estimated scheduling information presented in this section of the CDER has been obtained through the use of current and past in-house projects, vendor information, and the system and component reference schedule data in Section 5.2.3.

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4.1 PRELIMINARY DESIGN (TITLE I)

4.1.1 Studies

The preliminary design study was broken down into two sections and utilizes Figures 4-1, 4-2, and 4-3. Section 4.1.1 describes preengineering activities that must be completed before the project can proceed to the detail phase. Section 4.1.2 describes preliminary engineering activities.

4.1.1.1 Siting Considerations

Before any preliminary engineering can begin, a survey of siting possibilities must be undertaken. Many factors will be considered in choosing the site for the Magnetohydrodynamic-Engineering Test Facility (MHD-ETF). A reconnaissance survey of tentative sites would define many of the characteristics outlined below. At this point, a balancing analysis would be performed to determine the optimum choice with respect to engineering modifications and constructability versus project completion requirements.

1. Geography
   a. Location of cities and towns
   b. Population densities
   c. Climatic conditions
   d. Centers of housing, schools and medical facilities
   e. State and local building codes
   f. State and local health codes
   g. Constraints by environmental agencies and regulations
2. Geology
   a. Soil characteristics
   b. Seismic zones classification
   c. Bedrock characteristics
   d. Aquifer characteristics
3. Labor
   a. Supply/availability
   b. Quality of labor
   c. Productivity of labor

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MAGNETOHYDRODYNAMIC ENGINEERING TEST FACILITY

PRELIMINARY DESIGN (TITLE I)

DISCIPLINE	DESCRIPTION	LINE NO.
	SYSTEM DESIGN	1
	SITE STUDIES	2
	INITIAL IMPACT REPORTS	3
	INITIAL SELECTION AND EVALUATION OF VENDORS	4
	LICENSING APPLICATIONS AND APPROVALS	5
	PROJECT SCOPE, DESIGN CRITERIA, AND PMM	6
	ESTABLISH COAL TYPE - SULFUR CONTENT	7
	MAIN AND REHEAT STEAM PRELIMINARY SYSTEM DESIGN	8
	EXTRACTION STEAM PRELIMINARY SYSTEM DESIGN	9
	AUXILIARY STEAM PRELIMINARY SYSTEM DESIGN	10
	BOILER FEEDWATER PRELIMINARY SYSTEM DESIGN	11
	CONDENSATE PRELIMINARY SYSTEM DESIGN	12
	PRELIMINARY SYSTEM DESIGN FEEDWATER HEATER DRIPS	13
	PRELIMINARY SYSTEM DESIGN FEEDWATER HEATER AND MISC DRAINS	14
	PRELIMINARY SYSTEM DESIGN PLANT MAKEUP WATER	15
	PRELIMINARY SYSTEM DESIGN TURBINE PLANT SAMPLING	16
	PRELIMINARY SYSTEM DESIGN CIRCULATING WATER	17
	PRELIMINARY SYSTEM DESIGN CLOSED CYCLE COOLING WATER	18
	PRELIMINARY SYSTEM DESIGN FUEL OIL	19
	PRELIMINARY SYSTEM DESIGN BOILER FLUE GAS	20
	PRELIMINARY SYSTEM DESIGN PLANT INDUSTRIAL WASTE	21
	PRELIMINARY SYSTEM DESIGN FIRE SERVICE WATER	22
	PRELIMINARY SYSTEM DESIGN COAL MANAGEMENT	23
	PRELIMINARY SYSTEM DESIGN HVAC	24
	PRELIMINARY SYSTEM DESIGN MISCELLANEOUS ELECTRICAL	25
	PRELIMINARY SYSTEM DESIGN POWER SYSTEM	26
	PRELIMINARY SYSTEM DESIGN AC/DC DISTRIBUTION SYSTEM	27
	PRELIMINARY SYSTEM DESIGN COMMUNICATION	28
	MAGNET - SUPER CONDUCTOR	29
	COMBUSTOR	30
	CHANNEL	31
	INVERTER - TRANSFORMER	32
	COAL HANDLING AND INJECTION	33
	SEED INJECTION	34
	DIFFUSER	35
	CLEANUP	36
	SLAG REMOVAL	37
	HEAT EXCHANGE STEAM - GAS	38
	OXIDANT SUPPLY SYSTEM/ASU	39
	SINKS - CONDENSER - TOWER	40
	I & C ENGINEERING	41
	DATA ACQUISITION	42
	PERFORMANCE ASSURANCE PLAN	43
	RELIABILITY	44
	QUALITY ASSURANCE	45
	SAFETY ASSURANCE	46
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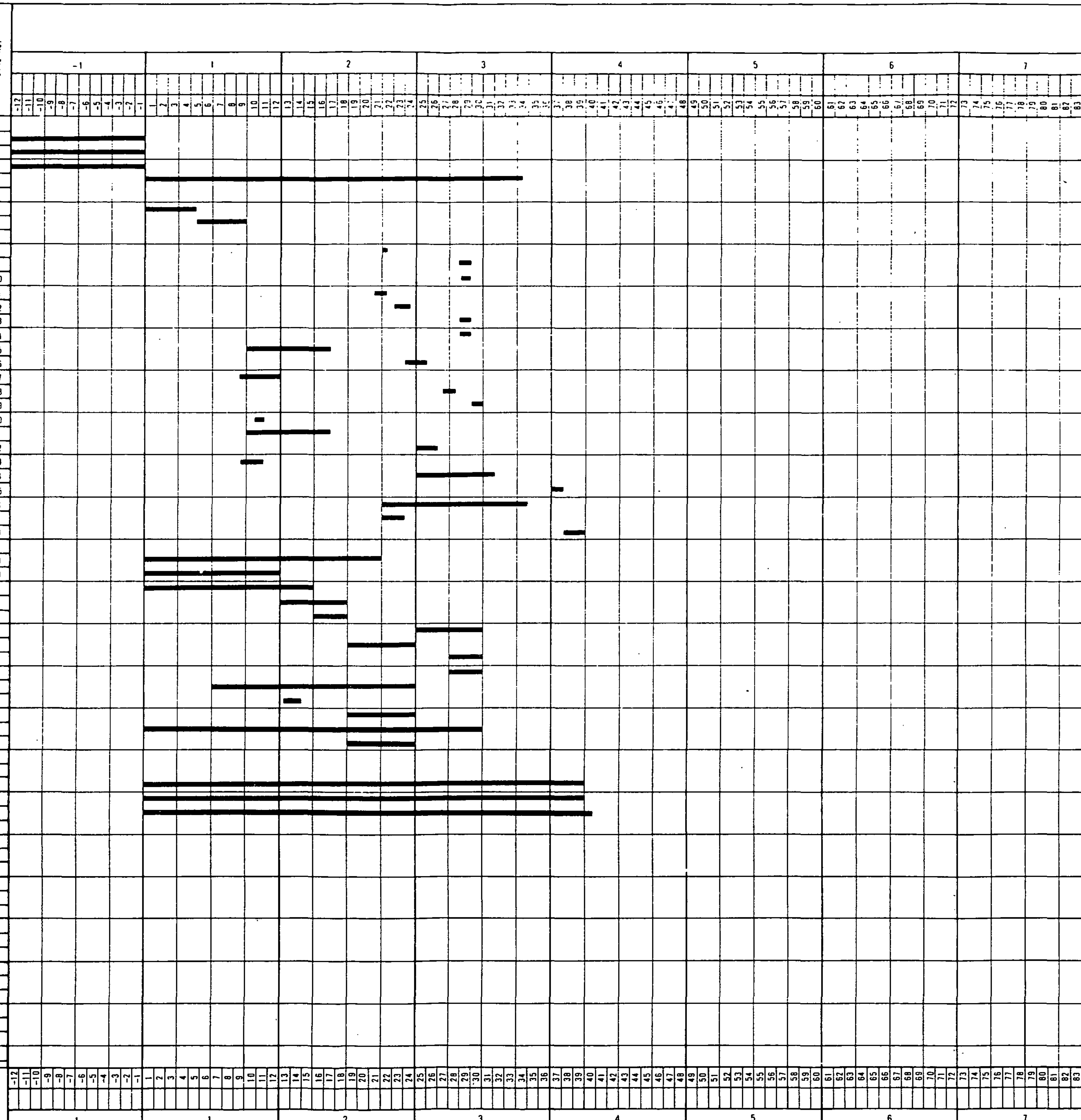

MILESTONE

YEAR

MONTH

REMARKS

FIGURE 4-1

MAGNETOHYDRODYNAMIC ENGINEERING TEST FACILITY

PACKAGE DESCRIPTION

DISCIPLINE	AREA	ACTIVITY	CONTRACT PACKAGE NO.	LINE NO.
		GENERAL SERVICES	1	1
		FENCING	2	2
		SITE PREPARATION	3	3
		SITE DEWATERING	3A	4
		ASH/SLUDGE DISPOSAL FACILITY	4	5
		CIRCULATING WATER SYSTEM	5	6
		RAILROAD CONSTRUCTION	6	7
		MATERIAL TESTING	7	8
		MAIN POWER BLOCK FOUNDATIONS	8A	9
		COOLING WATER SYSTEM FOUNDATIONS	8B	10
		COAL HANDLING FOUNDATIONS	8C	11
		MISCELLANEOUS FOUNDATIONS	8D	12
		PRECIPITATOR/FG FOUNDATIONS	8E	13
		ELEVATED CONCRETE DECKS	8F	14
		CONCRETE SUPPLY	9	15
		SPECIAL FINISH FLOOR	10	16
		CHIMNEY	12	17
		STRUCTURAL STEEL	13	18
		HVAC SYSTEMS	14	19
		MISCELLANEOUS HVAC SYSTEMS	14A	20
		CONTROL SERVICE AND DIESEL GENERATOR HVAC	14B	21
		STATION ENCLOSURES	15A	22
		STATION ENCLOSURES (MASONRY)	15B	23
		WAREHOUSE/TEMPORARY CONSTRUCTION BUILDING	16	24
		CONTROL, SERVICE, AUXILIARY BOILER BUILDING	17	25
		INTERIOR ARCHITECTURAL	18	26
		MISCELLANEOUS ARCHITECTURAL BUILDINGS	19	27
		FIRE PROTECTION - SPECIAL HAZARD	20	28
		YARD FIRE PROTECTION AND MISCELLANEOUS PIPING	21	29
		PAINTING	22	30
		STEAM GENERATOR	23	31
		COOLING TOWER	24	32
		MECHANICAL EQUIPMENT	25	33
		TURBINE GENERATOR	26	34
		PRECIPITATOR	27	35
		FGD SYSTEM	28	36
		GAS AND AIR DUCTS	29	37
		FIELD ERECTED TANKS	30	38
		COAL HANDLING SYSTEM	31A	39
		STACKER/RECLAIMER	31B	40
		PIPING - PHASE A	32A	41
		PIPING - PHASE B	32B	42
		ELECTRICAL - PHASE A	34A	43
		ELECTRICAL - PHASE B	34B	44
		INSTRUMENTATION	35	45
		INSULATION (PANEL)	36A	46
		INSULATION (PIPING/EQUIPMENT)	36B	47
		SERVICE ELEVATOR	37	48
		FINAL PAVING/SEED/LANDSCAPING	38	49
		HOLLOW METAL DOORS	39	50
		OVERHEAD ROLLING DOORS	40	51
		CHEMICAL CLEANING	41	52
		LAB EQUIPMENT	42	53
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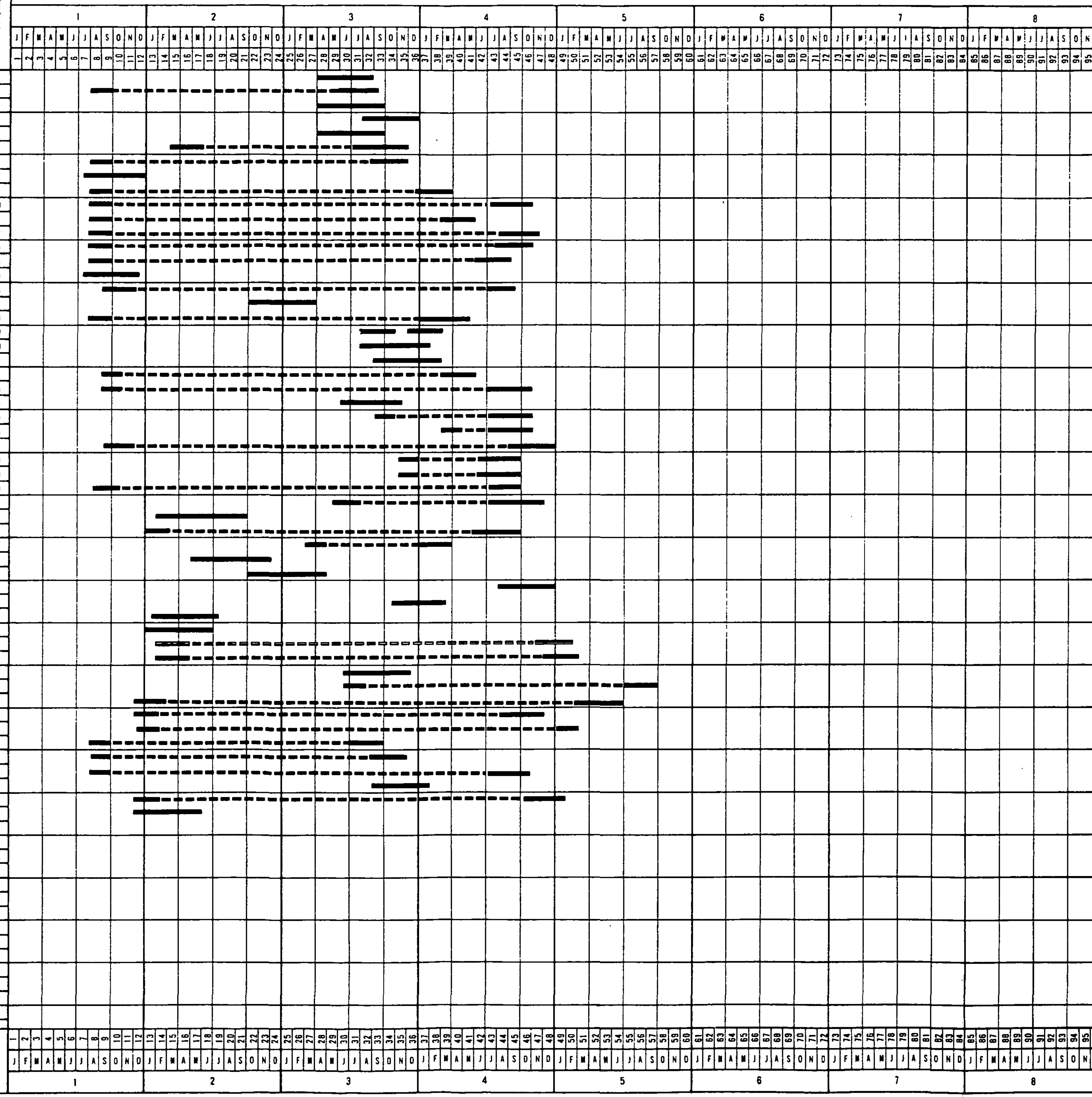

LINE NO.	MILESTONE YEAR MONTH	REMARKS

FIGURE 4-2

4-7/4-8

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MAGNETOHYDRODYNAMIC ENGINEERING TEST FACILITY
MILESTONE CHART

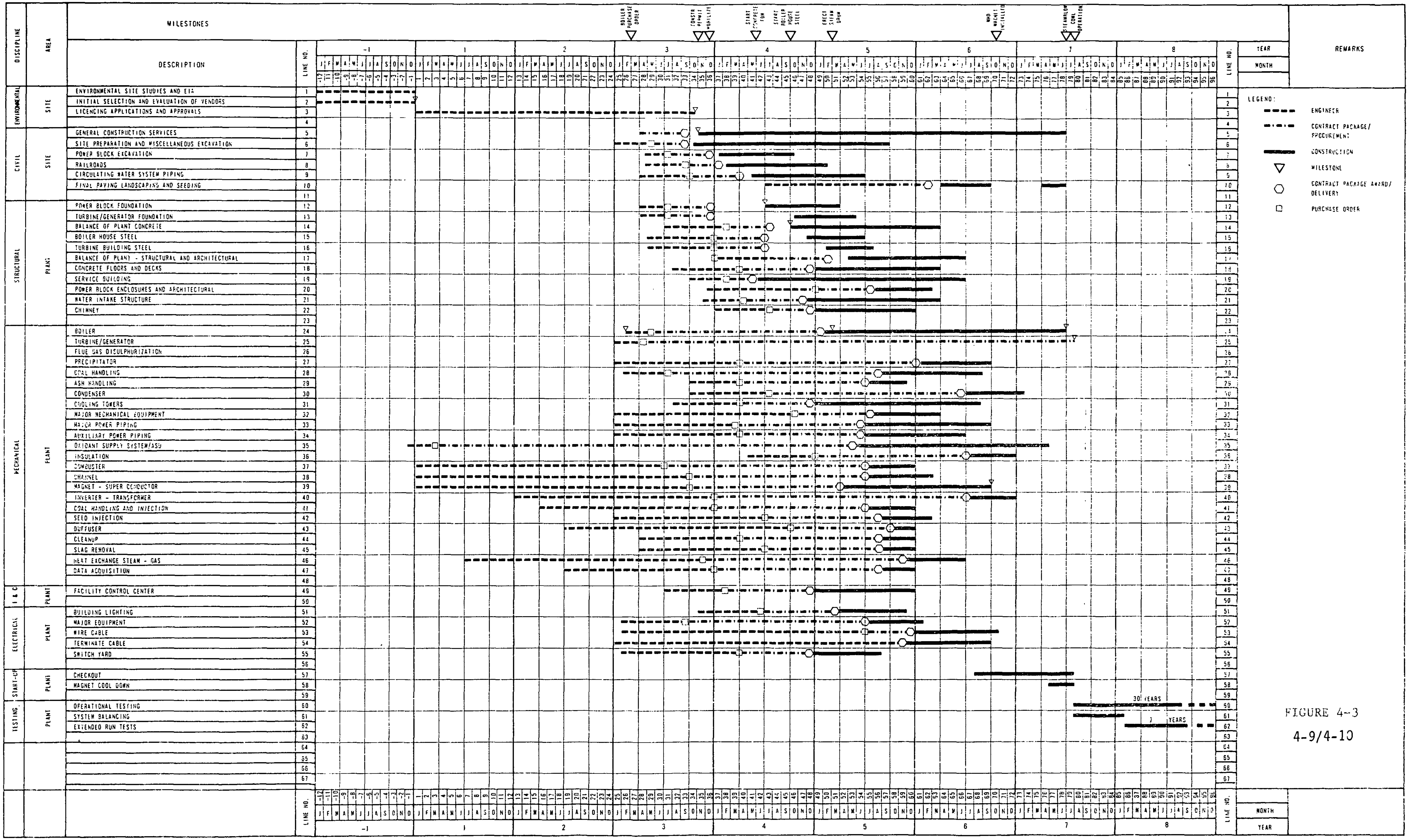

FIGURE 4-3

4-9/4-10

d. Competing construction projects

e. Union structure and jurisdiction

f. Union contract and negotiation profile

4. Transportation

a. Air

b. Rail

c. Bus

d. Highway

e. Water

5. Commercial

a. Availability of equipment and materials

b. Major contractor/vendor locations

c. Banks

d. Post office locations

e. Communications facilities

A time span of twelve months is required to complete the site study (See Figure 4-1).

4.1.1.2 Environmental Impact Analysis

Regulatory requirements are broad and far-reaching. A typical fossil plant may require tens of licenses or permits, each governing the start of specific project phases. For the purposes of the preliminary study, it is necessary to satisfy only those regulations which impact the initial engineering activities of the ETF. The balance of the licensing process occurs concurrently with, and is tied directly to engineering phase milestones (See Figure 4-3).

Information gathered from prototype studies and pre-engineering assumptions are used as a basis for filing environmental impact statements keyed to this level of design. Once this requirement is met, a higher order of engineering is begun, followed by more detailed guidelines.

To get the ETF into the engineering phase, the following items must be approved, any one of which could delay the front end of the project if the engineering proposal is not deemed acceptable.

1. Cooling system

2. Coal source

3. Air quality control system

4. Ash handling system and disposal area

5. Design and location of the intake and discharge structures

6. Coal handling system

7. Coal haulage routes

8. Plant layout

9. Chemical and sanitary water treatment systems

10. Total project water balance

11. Total project heat balance

12. Construction procedures including control of runoff and treatment of sanitary waste

13. Transmission routing

The interface between the design/engineering team and the environmental team should be rapidly established. Open lines of communication will expedite the processing of Environmental Impact Analysis (EIA) documents and will circumvent unnecessary delays in project completion. Responsible local, state and Federal authorities must also be identified and kept abreast of all activities pertaining to their area. This study assumes a best case situation with respect to EIA procedures justified by the critical nature of the MHD-ETF to the nation's energy future.

Experience with fossil plants serves as a basis for projecting a one year duration for the initial stages of the EIA licensing requirements (See Figure 4-1).

4.1.1.3 Licensing Requirements

Licensing is a complex and time-consuming requirement that is directly related to the progress, completion and startup of this project. The licensing procedure is phased, however, and can be done in the time allotted. It is estimated that thirty-four months will be required to obtain a construction permit once the EIA receives initial approval (See Figure 4-1 and 4-4). This time requirement is representative of an average based on past power plant experience. Many states have their own systems and procedures in this matter, but any extensions would be negligible when compared to the total allotted time for the project.

MAGNETOHYDRODYNAMIC ENGINEERING TEST FACILITY
DEFINITIVE DESIGN BY SYSTEM (TITLE II)

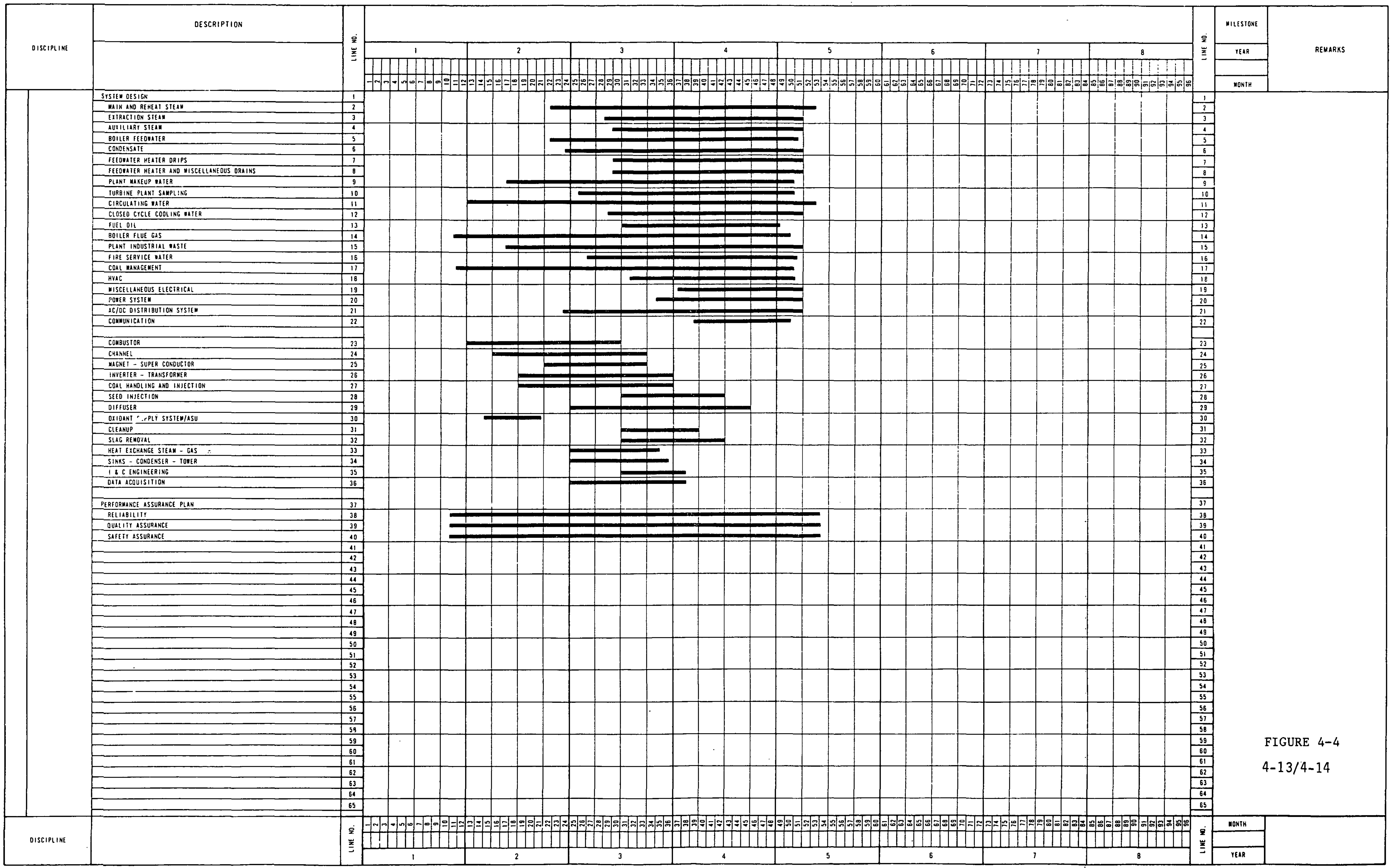

FIGURE 4-4

Several of the preconstruction permit procedures appear below with their corresponding time frames:

1.	Preliminary engineering and economic studies	6th-18th month
2.	Prepare Federal Environmental Impact Analysis	6th-16th month
3.	Prepare State Site Application	15th-24th month
4.	Federal Regulatory Review and Draft EIS Preparation	24th-36th month
5.	State Regulatory Review	24th-36th month
6.	Federal public hearings and final project approval	36th-48th month
7.	Construction permits/application approval	30th-48th month
8.	State public hearings and final project approval	36th-48th month
9.	Plant engineering for permit and approval	18th-39th month

4.1.1.4 Vendor Selection

The selection and evaluation of vendors is presented here as a contingency item. Magnetohydrodynamic technology is relatively new to electric generating stations and qualified vendor availability may be limited. A time frame of twelve months has been allotted to select vendors (See Figure 4-1).

For the bottoming cycle equipment for which there are industry standard systems and procedures, a customary bid procedure with appropriate time frames has been projected.

4.1.2 Engineering

In this section, engineering systems are defined and based on end product performance requirements. These requirements for the ETF were established in conceptual studies commissioned by the U.S. Department of Energy and supervised by NASA-Lewis Research Center. Consequently, the design of the scope items will be backed into these performance goals. Project control and management systems were developed and implemented concurrently with items here and in Section 4.1.

4.1.2.1 Project Outline and Controls

The Project Management Manual (PMM) is a definitive statement setting forth in-house engineering specialty interfaces, duties, and responsibilities. Also defined on a per project basis are guidelines that will be followed in dealing with outside services and vendors. This reference manual will take approximately five months to complete, as shown in Figure 4-1.

4.1.2.2 Performance Assurance Program Plan

Measures will be taken to ensure the safety of the public and ETF personnel and equipment. Quality assurance programs will also permit a realistic appraisal of plant operation.

The test facility will be designed and constructed to meet or exceed all existing local, state and Federal water, air and solid waste management requirements. The Occupational Safety and Health Standards of the Department of Labor, along with standards for occupational exposure to magnetic fields will serve as guides for the engineering, construction, and operational phases.

The Performance Assurance Program will run the full course of the project. As new standards come into effect as a result of technological advances or currently unforeseen conditions the personnel and procedures for quick action will be in place.

4.1.2.3 Bottoming Cycle Systems

The steam side, or bottoming cycle, is for the most part an industry standard system. Subsystems in a fossil plant have known dependency on other systems and systems are designed sequentially. For example, Figure 4-1 shows that the circulating water system design begins in the ninth month, while power system design proceeds in the twenty-first month. Also, time durations vary widely between different systems in this section. The circulating water system has a duration of three and one-half months for this phase of engineering, while the power system has a preliminary design time of thirteen months (See Figure 4-1).

The basic bottoming cycle systems being explored in this phase are as follows:

1. Electric generation system
2. Water circulation system
3. Boiler/steam generation system
4. Coal management system
5. AC distribution system
6. Instrumentation and control system

4.1.2.4 MHD Systems

Systems associated with MHD will be monitored much more intensively than the bottoming cycle systems with special concern for the bi-system interface hardware.

The basic topping cycle systems being explored in this phase are as follows:

1. Channel power inverter system
2. Combustor system
3. MHD channel system
4. Magnet construction system
5. Steam generating and regeneration system
6. Seed handling, injection, recovery and regeneration system
7. Diffuser system
8. Instrumentation and control system
9. Pollution control system
10. Oxidant supply system and ASU

Preliminary engineering of idealized MHD systems has been done. It has been assumed that pertinent data will be available as required.

Review of Figure 4-1 shows the effort from month one through month thirty to bring the engineering of the MHD system design to the level of those of the bottoming cycle systems.

4.2 DEFINITIVE DESIGN (TITLE II)

In this project phase, facility components are addressed and governing critical data are quantified through the use of packages, (Section 4.2.1), systems (Section 4.2.2), and structures (Section 4.2.2.3). The last two sections describe the operating equipment, and structural/civil structures, respectively.

4.2.1 Packages

This breakdown groups related activities. For example, structural steel is ordered while general assumptions are still being made about overall plant design. Each package is delivered as it is needed. The bar chart follows the activity until it is no longer active in-house. In the case for structural steel, this is month thirty-four.

Other package types that have long in-house activity include railroad construction which begins in month seven and extends twenty-seven months. The piping and electrical packages also extend for a period of approximatly thirty-six months. For systems such as coal handling equipment, only a specification is needed for procurement from vendors. Therefore, its duration time is comparatively short, beginning at month twelve and extending for six months (See Figure 4-5).

4.2.2 Systems

4.2.2.1 Topping Cycle

1. Pollution Control

   The pollution control system is required to meet or surpass all Federal, state and local environmental regulations which apply to the emission characteristics of this facility. Special systems may be designed during this phase which will reduce sulfur, particulate and NOx percentages as required. A seed recovery system interfaces with the emission components and is discussed in Section 4.2.2.1, Subsection 8. Performance Assurance has an impact here together with environmental impact licensing procedures. The expected duration for the final design of this system is nine months.

2. Power Converter

   This system is designed to change the direct current produced by the MHD generator into alternating current. There are also mechanisms which protect the electrical system of the ETF from disturbances caused by the MHD power train. Duration of the final design of this system is eighteen months.

3. Combustion

   The combustor is designed to provide a high temperature gas stream into which potassium salts (seed) are injected and ionized. Duration for the final design of this system is projected at eighteen months.

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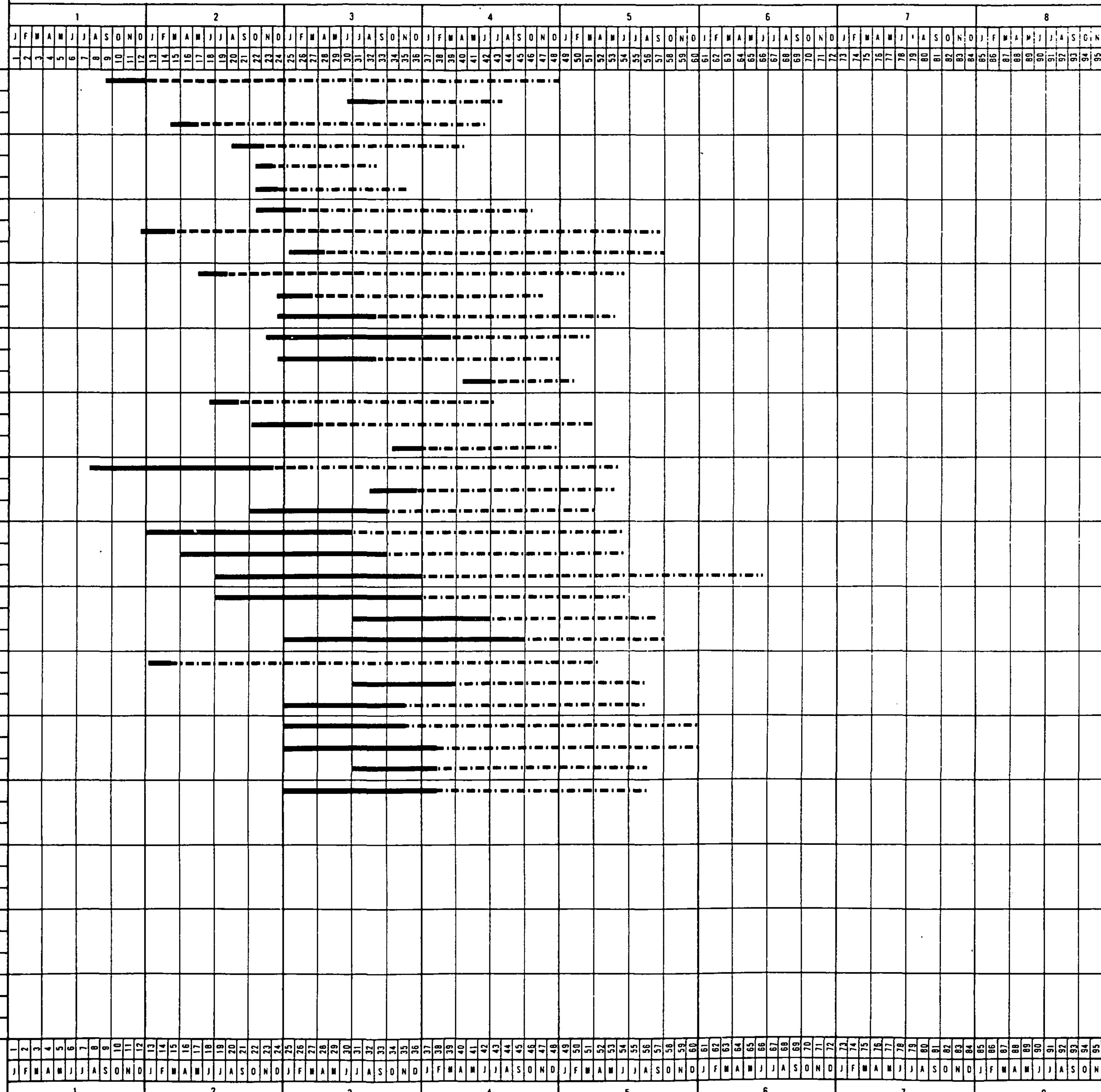
MAGNETOHYDRODYNAMIC ENGINEERING TEST FACILITY
SPECIFICATION, PROCUREMENT, AND FABRICATION

LINE NO.	ACTIVITY
1	BOILER
2	AUXILIARY BOILERS
3	TURBINE/GENERATOR
4	CONDENSER
5	DEAERATOR AND STORAGE TANK
6	BOILER FEED PUMP
7	FEEDWATER HEATERS
8	CIRCULATING WATER CHEMICAL TREATMENT
9	TURBINE PLANT SAMPLING
10	INDUSTRIAL WASTE TREATMENT
11	GENERATOR CIRCUIT BREAKER
12	SWITCHGEAR MEDIUM VOLTAGE
13	INVERTER SYSTEM
14	DIESEL GENERATOR
15	COMMUNICATIONS SYSTEMS
16	BURNER CONTROL AND FUEL SAFETY SYSTEM
17	PLANT COMPUTER
18	EMISSION MONITORING SYSTEM
19	REMOTE MULTIPLEXING
20	MAIN CONTROL ROOM PANELS
21	MAGNET - SUPER CONDUCTOR
22	COMBUSTOR
23	CHANNEL
24	INVERTER - TRANSFORMER
25	COAL HANDLING AND INJECTION
26	SEED INJECTION
27	DIFFUSER
28	OXIDANT SUPPLY SYSTEM/ASU
29	CLEANUP
30	SLAG REMOVAL
31	HEAT EXCHANGE STEAM - GAS
32	SINKS - CONDENSER - TOWER
33	I & C ENGINEERING
34	DATA ACQUISITION



LEGEND:-
PREPARATION SPECIFICATIONS
BID PROCEDURES
FABRICATE AND DELIVER

FIGURE 4-5

4. Magnetohydrodynamic Channel

The channel and its support components produce and extract the electrical power generated as the plasma passes through the magnetic field. Projected design time is eighteen months.

5. Super-Conducting Magnet

This magnet system is supported by a cryogenic cooling system, a vacuum system, water circulating system interface, a regulated power supply system, and a cooling system. A twelve month design effort is allotted.

6. Steam Generation and Heat Recovery System

The purpose of the components comprising these systems are to extract and use as much thermal energy as practicable from the MHD downstream gases. This system interfaces with the steam/turbine generator system. We project that it would take ten and one-half months to complete the design engineering phase.

7. Instrumentation and Control System

MHD generator processes will be controlled by a Main Facility Control Subsystem. By utilizing various sensory devices, the subsystem will automatically regulate the combustor, generator, and plasma conductivity to achieve stable power-train performance. It will also regulate and protect support systems such as the cryogenic cooling system and the vacuum system. The engineering of these controls should be completed in eight months.

8. Seed Injection and Recovery

The seed will be injected into the combustor to be ionized and will combine with the sulfur present in the flue gas. Sulfur laden seed will be collected and recycled. Twelve months have been allotted for the engineering of this system.

9. Diffuser System

The diffuser section is designed to decelerate the nearly sonic speeds of combustor exhaust gas after it leaves the MHD channel. We project an engineering completion time of twenty-one months.

10. Oxidant Supply System and ASU

This system provides oxygen rich oxidant to the combustor. After receipt of contract the selected Vendor will have the system on site in three years.

4.2.2.2 Bottoming Cycle

1. Power Generation System

   The generator will be powered by a steam turbine of conventional design. The generator itself will also be of conventional design. Based on experience with fossil plants, seventeen months for the engineering of this system has been allotted.

2. Circulating and Feedwater System

   The ETF has two distinct power generating systems using the circulating and feedwater system. Forty-one months for engineering design has been allotted.

3. AC Distribution System

   Commercial performance responsibility has been assumed for main power grid electrical supply. Such systems are normally complex so a time duration of twenty-eight months has been allowed for design.

4.2.2.3 Structures

This section defines the architectural buildings and civil engineering work required of the site. The bulk of the design and drawings can be completed within twelve to fourteen months (See Figure 4-2 and 4-6). The major facilities required to house the systems described in Section 4.2.2 are as follows:

1. Turbine Generator Building

   Typical steel and concrete bay construction.

2. MHD Building

   A major requirement here is for the construction to shield employees and equipment from exposure to strong magnetic fields. Minor customized structural modifications are required for magnet support during operation and movement during maintenance.

3. Boiler Building

   Typical steel and concrete bay construction.

4. Coal Handling Facilities

   Sixty day storage. Conveyor and coal pulverizing equipment are part of industry standard systems.

Civil work such as railroad spur construction, parking lots, drainage requirements, and grading would be determined by the actual site. Experience indicates, however, that sixteen months should be allowed.

MAGNETOHYDRODYNAMIC ENGINEERING TEST FACILITY

DEFINITIVE DESIGN BY AREA (TITLE II)

DISCIPLINE	DESCRIPTION	LINE NO.
	SITE GRADING/DRAINAGE, CIVIL YARD PIPING COMPOSITES	1
	DESIGN AND DRAWINGS - LAYOUT	2
	SEED UNLOAD AND STORAGE	3
	CONTROL COMPLEX	4
	BOILER BUILDING	5
	TURBINE GENERATOR BUILDING	6
	MAGNETOHYDRODYNAMIC BUILDING	7
	ADMINISTRATION BUILDING	8
	INTAKE STRUCTURES	9
	DESIGN AND DRAWINGS - CONCRETE	10
	SEED UNLOAD AND STORAGE	11
	CONTROL COMPLEX	12
	BOILER BUILDING	13
	TURBINE GENERATOR BUILDING	14
	MAGNETOHYDRODYNAMIC BUILDING	15
	ADMINISTRATION BUILDING	16
	INTAKE STRUCTURES	17
	DESIGN AND DRAWINGS - STEEL DECKING	18
	SEED UNLOAD AND STORAGE	19
	CONTROL COMPLEX	20
	BOILER BUILDING	21
	TURBINE GENERATOR BUILDING	22
	MAGNETOHYDRODYNAMIC BUILDING	23
	ADMINISTRATION BUILDING ROOF	24
	DESIGN AND DRAWINGS - ARCHITECTURAL	25
	BOILER BUILDING	26
	CONTROL COMPLEX	27
	TURBINE GENERATOR BUILDING	28
	MAGNETOHYDRODYNAMIC BUILDING	29
	ADMINISTRATION BUILDING	30
	CABLE TRAY DRAWINGS	31
	SEED UNLOAD AND STORAGE	32
	BOILER BUILDING	33
	CONTROL COMPLEX	34
	TURBINE GENERATOR BUILDING	35
	MAGNETOHYDRODYNAMIC BUILDING	36
	ADMINISTRATION BUILDING	37
	DESIGN AND DRAWINGS - STRUCTURAL STEEL	38
	SEED UNLOAD AND STORAGE	39
	CONTROL COMPLEX	40
	BOILER STEEL	41
	TURBINE GENERATOR BUILDING	42
	MAGNETOHYDRODYNAMIC BUILDING	43
	INTAKE STRUCTURES	44
	POWER BLOCK EXCAVATION	45
	RAILROADS	46
	CIRCULATING WATER SYSTEM PIPING	47
	FINAL PAVING LANDSCAPING AND SEEDING	48
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MILESTONE YEAR MONTH — 1 2 3 4 5 6 7 8 — REMARKS

FIGURE 4-6

4.3 PROCUREMENT, FABRICATION, AND CONSTRUCTION

4.3.1 Procurement

Two different procedures will be used in this phase of project planning. For the bottom cycle systems, normal specification and bidding procedures will be followed. The MHD systems will have vendor input from the beginning, flowing through preliminary system engineering, definitive design, equipment design and into the specification period. Experience is limited in both the design and manufacturing procedures. Certain, contracts will be awarded on a negotiated basis. Reference Figure 4-7 for this section.

MHD systems will be fabricated and ready for delivery by month fifty-nine, with one exception. The inverter/transformer system will not be ready for delivery until month sixty-five. This makes it a critical system with a time frame of fifty-two months for delivery and installation.

Another piece of equipment which must be monitored closely will be the construction of the superconducting magnet. Because the unit is too large to transport, it must be fabricated on site. Activities such as the erection of steel and the forming and pouring of concrete in the building housing the magnet will have to be coordinated from the magnet fabrication schedule.

The oxidant supply system/ASU, will also be assembled on site. The selected vendor will have the capability for turnkey installation. Construction time will be three years.

Bottoming cycle systems have been projected from similar fossil plant experience. Determining activities in this phase of project planning are the circulating water system, and the turbine plant sampling system. The components of these systems should be fabricated and ready for delivery in month fifty-seven.

4.3.2 Fabrication and Construction

In comparison to the construction activities of the bottoming cycle systems, the placement and connection of the topping cycle systems are short, aside from the placement and connection of the superconducting magnet, which will require eighteen months. The inverter system, which requires six months to place and connect, is typical of the MHD systems. Reference Figure 4-7 for this section.

Critical items affecting the completion of construction include the coal handling system, electric power production system, the installation of the instrumentation and control system, and parts of the pollution control system.

Two elements of critical importance in the coal handling system are the rail-car manipulation equipment and the control building equipment. These items should be completed by month sixty-nine.

Critical components of the electric power production system include turbine generator erection, the substation, and the transformers. These items should

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MAGNETOHYDRODYNAMIC ENGINEERING TEST FACILITY

CONSTRUCTION

DISCIPLINE	DESCRIPTION	LINE NO.
	SITE PREPARATION V/G DUCT BANKS, YARD PIPING, WAREHOUSE, ETC	1
	ROTARY CAR DUMPER	2
	CAR THAWING SHED	3
	COAL SYSTEM CONTROL BUILDING	4
	FUEL OIL TANK; DIKE AND PUMP HOUSE	5
	INTAKE STRUCTURE	6
	30 DAY COAL PILE STORAGE	7
	WAREHOUSE	8
	STORAGE TANKS – FILTERED, FIRE SERVICE, DEMINERALIZED AND CNDS WATER	9
	ADMINISTRATION, SERVICE, AND MACHINE SHOP	10
	COOLING TOWERS AND CIRCULATING WATER PUMP HOUSE	11
	COAL CONVEYING SYSTEM	12
	AUXILIARY BOILERS	13
	TRANSFORMERS	14
	CONTROL ROOM	15
	SUBSTATION	16
	CHIMNEY	17
	I.D. FANS	18
	INDUSTRIAL WASTE TREATMENT BUILDING	19
	MAIN GUARDHOUSE	20
	MAKEUP CYCLE PRETREATMENT AND CONDENSATE POLISHING BUILDING	21
	100 MW TURBINE BUILDING	22
	TURBINE/GENERATOR ERECTION	23
	ELECTROSTATIC PRECIPITATOR	24
	BOILER ERECTION	25
	COMBUSTOR	26
	CHANNEL	27
	MAGNET – SUPER CONDUCTOR	28
	INVERTER	29
	COAL HANDLING AND INJECTION	30
	SEED INJECTION	31
	OXIDANT SUPPLY SYSTEM/ASU	32
	DIFFUSER	33
	CLEANUP	34
	SLAG REMOVAL	35
	HEAT EXCHANGE STEAM – GAS	36
	SINKS – CONDENSER – TOWER	37
	I & C ENGINEERING	38
	DATA ACQUISITION	39
	PERFORMANCE ASSURANCE	40
	RELIABILITY	41
	QUALITY ASSURANCE	42
	SAFETY ASSURANCE	43
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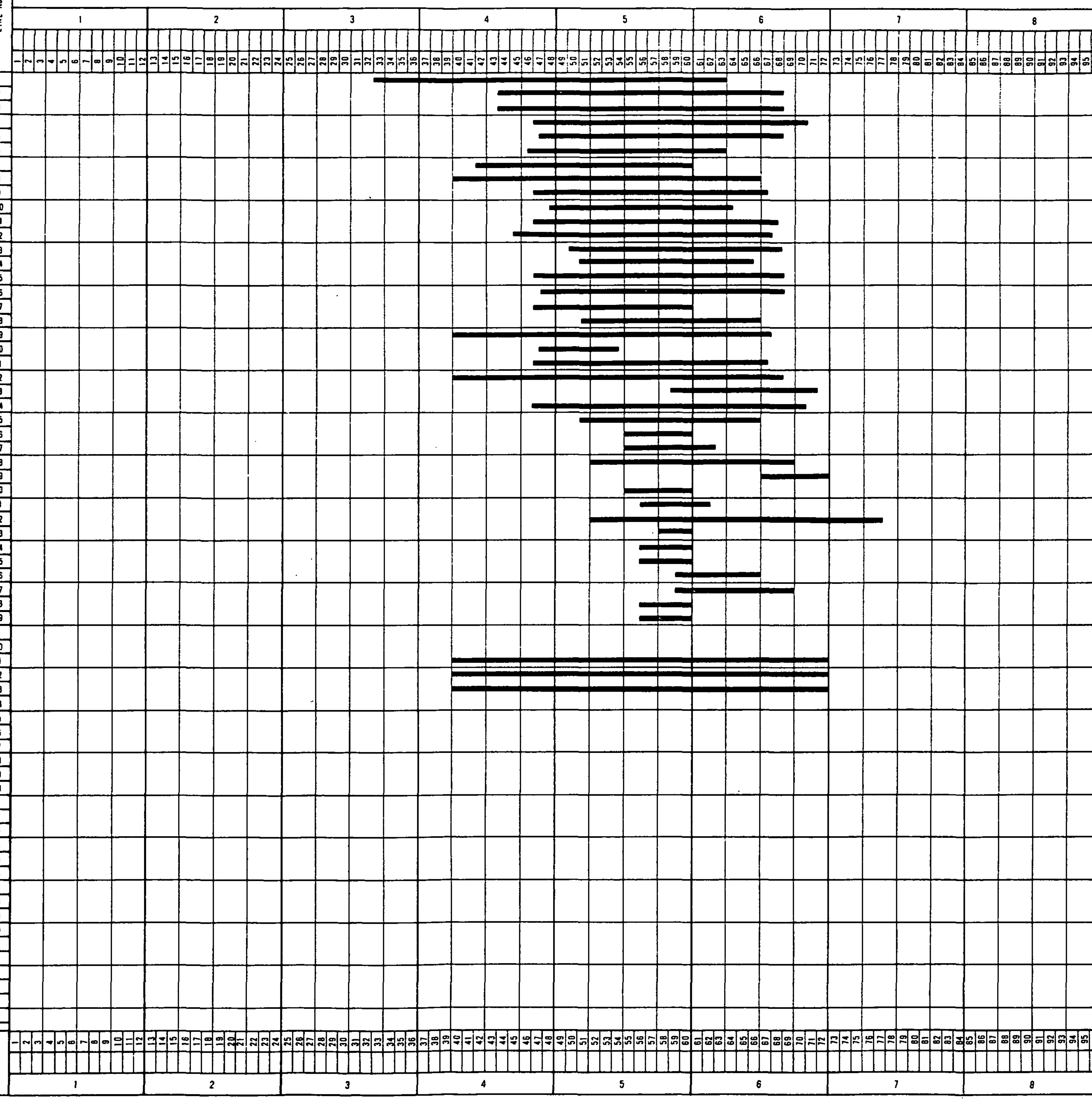
DISCIPLINE		LINE NO.



LINE NO.	MILESTONE	REMARKS
	YEAR	
	MONTH	

MONTH

YEAR

FIGURE 4-7

4-29/4-30

be installed and connected by the end of the sixty-ninth and sixty-seventh month, respectively.

The installation of the instrumentation and control system should be completed by the end of the sixty-ninth month.

Correct operation of the pollution control system is important for final licensing approvals before plant operation is permitted. The electrostatic precipitator, which will remove most of the suspended particles from the flue gas, will be installed and in operational condition by the end of month seventy.

4.4 TESTING

During the check-out phase, the projects systems components are tested on an individual basis; systems are tested on a system by system basis; system interfaces are checked and system/system interactions are gauged against specifications.

Time durations vary for each test, but the coordinated check- out phase is allotted 11 months (See Figure 4-8) .

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MAGNETOHYDRODYNAMIC ENGINEERING TEST FACILITY

CHECKOUT AND TESTING

DISCIPLINE	AREA	ACTIVITY	CONTRACT PACKAGE NO.	LINE NO.
		CHECKOUT		1
		ENERGIZE STATION SERVICE		2
		P/O TEST AC DISTRIBUTION		3
		P/O TEST CONDENSATE SYSTEM		4
		P/O TEST FEEDWATER SYSTEM		5
		COLD WATER CONDENSATE/FEEDWATER FLUSH		6
		CLEAN, NEUTRALIZER, AND RESTORE		7
		P/O TEST HEATER DRIPS AND VENTS		8
		BOILER HYDRO		9
		FIRST FIRE BOILOUT		10
		STEAM BLOW		11
		ROLL TURBINE		12
		LOAD TEST		13
		MAGNET COOLDOWN		14
		COMMERCIAL OPERATION		15
		PERFORMANCE ASSURANCE PLANT		16
		RELIABILITY		17
		QUALITY ASSURANCE		18
		SAFETY ASSURANCE		19
				20
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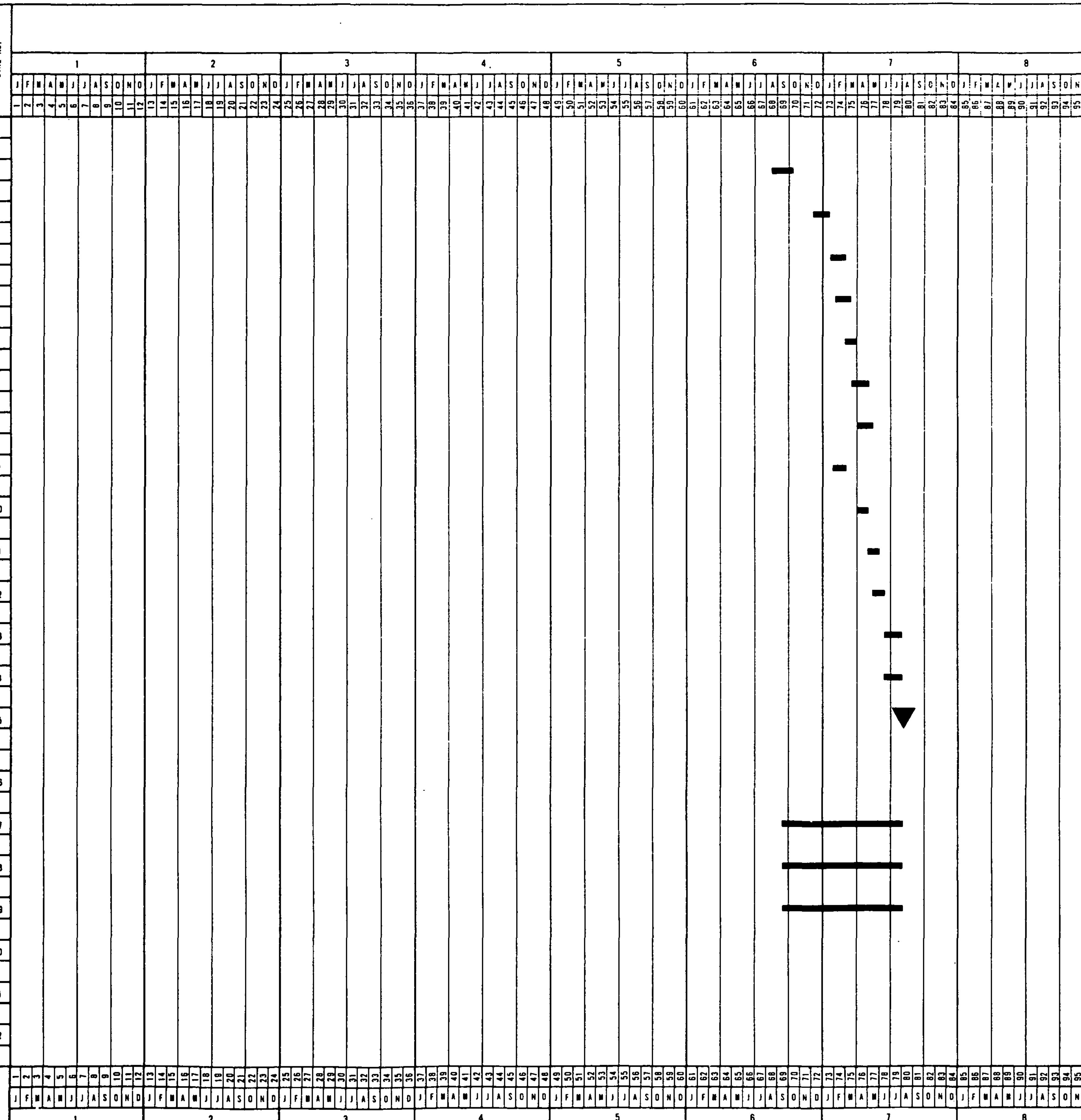

MILESTONE / YEAR / MONTH — REMARKS

FIGURE 4-8

4.5 OPERATIONS

The operation of the Engineering Test Facility will be broken down into two phases. Phase one will be a test period lasting for two and one-half years, and phase two will be commercial operation lasting for twenty-seven and one-half years.

4.5.1 Test Facility

During the first six months of thirty operating as a test facility, system capacities and performance will be analyzed and established. Instruments and controls will be debugged and the topping and bottoming cycle systems will be tuned and balanced. In the remaining twenty-four months, extended run times will be executed. Performance will be monitored and maintenance procedures refined.

4.5.2 Commercial Facility

By this time the Engineering Test Facility should have the necessary experience behind it, both in personnel and equipment, to perform reliably. A monitoring procedure will still be in effect to allow for long term study and maintenance of the system.

SUMMARY

Based on an overall Milestone Schedule (See Figure 4-3) related to conventional power plant scheduling experience and starting procurement of MHD components during the preliminary design phase, there is a 6-1/2 year construction period. This assumes that the MHD technology will be available to satisfy manufacturing, final design and construction schedule requirements. These schedules correspond to those which would develop from normal practice of the electric utility industry and do not take into account the effect of government requirements for phased funding and approval. Accordingly, the schedules are considered representative of the "ideal" times required to design and construct an ETF stand alone power facility.

As indicated, the duration between Boiler purchase order (PO) and Commercial Operation is fifty-three months, while the overall duration of the project from Project Start to Commercial Operation is seventy-nine months. Actual project duration normally is controlled by the licensing phase, with approximately forty-six months of licensing preceding site work, followed by forty-five months of construction and startup. This gives an overall duration of ninty-one months.

The engineering phase of the project is four and one half years, beginning with the mobilization of the project team. Engineering from Boiler P.O. to the start of the main power block foundation placements is fifteen months. The construction duration, following the start of the main power block foundation is thirty-seven months. This period also includes startup activity.

Operational life of the ETF will be 30 years, the first 2-1/2 of which will be an operational test phase.

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15. Supplementary Notes

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16. Abstract

This report summarizes the reference conceptual design of the MHD Engineering Test Facility (ETF), a prototype 200 MWe coal-fired electric generating plant designed to demonstrate the commercial feasibility of open cycle MHD. Main elements of the design are identified and explained, and the rationale behind them is reviewed. Major systems and plant facilities are listed and discussed. The report also presents construction cost and schedule estimates, and identifies the engineering issues that should be reexamined. This report integrates the latest (1980-1981) information from the MHD technology program with the elements of a conventional steam power electric generating plant. It is presented in five volumes:

- Vol. I - Executive Summary
- Vol. II - Engineering
- Vol. III - Costs & Schedule
- Vol. IV and Vol. V - Supplementary Engineering Data (Issues, Background, Performance Assurance Plan, Design Details, System Design Descriptions and Related Drawings).

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